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ABSTRACT

Science programs funded by the National Science Foundation (NSF) are increasingly involved in science education reform. Such entities are funded for science research and are expected to pursue educational activities with K-12 students and teachers. These efforts are often guided by ideas from current science education reform. The NSF Science and Technology Center for Sustainability of Semi-Arid Hydrology and Riparian Area (SAHRA) has established an educational goal of hydrologic literacy, modeled on reform for scientific literacy. One of SAHRA's educational programs involves creation of a regionally focused water curriculum. This collaborative effort involves secondary teachers, science and policy experts, and science educators creating multidisciplinary curriculum that integrates the sciences and other academic fields. The purposes of this study were to characterize goals of the project and the individual goals of participants and to use such understanding to facilitate curriculum completion and implementation. As integral research, this study adopted a constructivist perspective to pursue description and interpretation of individual intention and collective socio-cultural phenomena. Research strategies of applied ethnography and grounded theory guided the collection and analysis of interviews with participants, meeting notes, e-mail, curriculum modules, and journals. Findings indicate that participants share a common conception of a innovative multidisciplinary curriculum while holding differing images of the goals of SPLASH in terms of educational reform and practice with conflicting interests in recruitment of qualified students into science, meaningful learning among students, cutting edge content, innovative practice, and professional development. These differences have forced participants to engage in active construction of integrity through the adoption of a modular structure and a commercial curriculum development template. (Author)

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Creation of a Multidisciplinary Curriculum for Hydrologic Literacy: An Applied Ethnography

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ABSTRACT

Science programs funded by NSF are increasingly involved in science education reform. Such entities are funded for science research and are expected to pursue educational activities with K-12 students and teachers. These efforts are often guided by ideas from current science education reform. The NSF Science and Technology Center for Sustainability of Semi-Arid Hydrology and Riparian Areas (SAHRA) has established an educational goal of hydrologic literacy, modeled on reform for scientific literacy. One of SAHRA's educational programs involves creation of a regionally focused water curriculum. This collaborative effort involves secondary teachers, science and policy experts, and science educators creating a multidisciplinary curriculum that integrates the sciences and other academic fields. The purposes of this study were to characterize the goals of the project and the individual goals of participants and to use such understanding to facilitate curriculum completion and implementation. As integral research, this study adopted a constructivist perspective to pursue description and interpretation of individual intention and collective socio-cultural phenomena. Research strategies of applied ethnography and grounded theory guided the collection and analysis of interviews with participants, meeting notes, e-mail, curriculum modules, and journals. Findings indicate that participants share a common conception of a innovative multidisciplinary curriculum while holding differing images of the goals of SPLASH in terms of educational reform and practice with conflicting interests in recruitment of qualified students into science, meaningful learning among students, cutting edge content, innovative practice, and professional development. These differences have forced participants to engage in active construction of integrity through the adoption of a modular structure and a commercial curriculum development template.

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INTRODUCTION & BACKGROUND

Science programs funded by the National Science Foundation (NSF), such as university-based Science and Technology Centers (STC), are becoming increasingly involved in science education reform. Such entities are well funded to pursue innovative science research and are expected to engage in educational activities that reach many audiences including the general public, K-12 students and teachers, and field-related professionals. Science and Technology Centers in particular are challenged to move beyond engaging a large educational audience to facilitating change (Mervis, 2002). In many instances, these educational activities are guided by the goals and standards associated with current science education reform. For example, the Center for Adaptive Optics at the University of California in Santa Cruz created *Stars, Sight, and Science*, a summer course for minority high school students, to promote inquiry, a key feature of the National Science Education Standards (NSES; NRC, 1996).

The NSF STC for Sustainability of Semi-Arid Hydrology and Riparian Areas (SAHRA) has organized its education efforts around the goal of hydrologic literacy, modeled after scientific literacy in the NSES. SAHRA was created to "develop an integrated, multi-disciplinary understanding of the hydrology of semi-arid regions, and to building partnerships with a broad spectrum of stakeholders (public agencies and private firms) so that this understanding is effectively applied to the optimal management of water resources and to the rational implementation of public policy" (SAHRA, n.d., ¶ 2). Although SAHRA is a science institution, its integrated, interdisciplinary vision recognizes science's position as a human endeavor occurring in the context of politics, education, economics, values, and science research. This vision is paralleled by recognition that science education and outreach efforts not only transmit knowledge; they also transmit conceptions of the nature and culture of science (Dixon, Spiegel, & Papagiannis, 1998).

Reflecting SAHRA's efforts at integration, one of its educational programs (see Appendix A for a display of all SAHRA educational programs) involves creation of a Student-Centered Program for Learning About Semi-Arid Hydrology (SPLASH). SPLASH is a collaborative effort among high school science and social science teachers, science and policy experts, and science educators to create and implement a regionally focused water curriculum. The curriculum is multidisciplinary, integrating the sciences and other academic fields. This undertaking involves individuals with varying perspectives attempting to achieve a common goal. Such an effort demands that individuals generate integrity, navigating among individual intentions and collective socio-cultural structures (Palmer, 1998; Wilber, 2000).

The teachers involved in SPLASH have power and voice in crafting a reform effort sponsored by a non-K-12 public education institution. Typical models of educational reform concentrate on transmitting content and curricula in ways that have a "demeaning, de-skilling, and demoralizing effect…on teachers" (Parke & Coble, 1997). There is considerable support for educational change that involves active participation of teachers in decision-making and that is driven by teachers' concerns (Ben-Chaim, Joffe & Zoller, 1994; Dandridge, 1993; Loucks-Horsley, Hewson, Love & Stiles, 1998). One example of a teacher-driven reform effort was a NASA funded project involving a collaborative partnership of scientist-teacher teams to develop scientifically up-to date lessons aligned with the NSES (Slater, Beaudrie, Cadtiz, Governor, Roettger, Stevenson, & Tuthill, 2001). Pilot testers and primary field testers found that the lessons were relevant and could be used immediately in

the classroom. In addition, the teachers expressed the desire to continue using the lessons in their curricula.

One of us (Hancock) was hired by SAHRA after the inception of SPLASH to administer its educational programs and develop a related research program. It quickly became apparent that while SPLASH had a clearly articulated goal of creating and implementing a curriculum that emphasizes hydrologic literacy in the context of the semi-arid southwest, the pedagogical goals of SPLASH as a whole and of the participants as individuals were unclear. The purposes of this study were to more clearly articulate these goals and use such understanding to facilitate the completion and implementation of the SPLASH curriculum. Specifically, this study sought answers to the following questions:

- What are participants' understandings of the overall goals of SPLASH in terms of content, educational reform, and practice?
- What are participants' understandings of their personal goals for involvement with SPLASH in terms of content, educational reform, and practice?
- How have participants achieved integrity in this context, and what are the key factors involved in this?
- How does this effort inform the educational practices of entities like SAHRA?

While this study specifically seeks to guide the continued work of SPLASH, it can also contribute to general understandings in the field of science education in three ways. First, there are many science institutions like SAHRA engaged in education as part of their larger goals of advancing scientific understandings. The findings from this research can guide the work of such institutions in collaboration with teachers. Second, this research presents images of teachers exercising voice and power in reform efforts; currently few such images exist. Third, this study also develops images of various dimensions of multidisciplinary reform including collaboration among teachers, scientists, and science educators and integration of sciences and other disciplines in a high school curriculum.

THEORETICAL FRAMEWORK

Just as SAHRA seeks integrated knowledge, and SPLASH seeks multidisciplinary learning, this research was undertaken from an integral perspective. The integral model of human understanding draws on the knowledge of many fields of scholarly endeavor to present a map of how humans engage and make sense of the world (Figure 1; Wilber, 2000). This complex model involves two primary elements: multiple perspectives and a spectrum of development. The multiple perspectives are exterior, individual elements of a phenomenon that are generally represented by observable behavior; exterior, collective considerations that are social in nature; interior, collective understandings that are ascribed to culture; and interior, individual intentions. Within and across each of these four perspectives there is development. This development tends to move from preconventional egocentric orientations grounded in meeting survival needs to sociocentric orientation focused on maintenance of socio-cultural structures to pursuit of individual achievement through rational processes to postconventional perspectives from a world centric orientation that focuses on systemic understandings. Such models are often interpreted as hierarchies devised for static labels. Rather than serving as a way to sort phenomena, individuals, and concepts, the integral model reflects a dynamic conception of the interacting influences of various perspectives and levels of development.

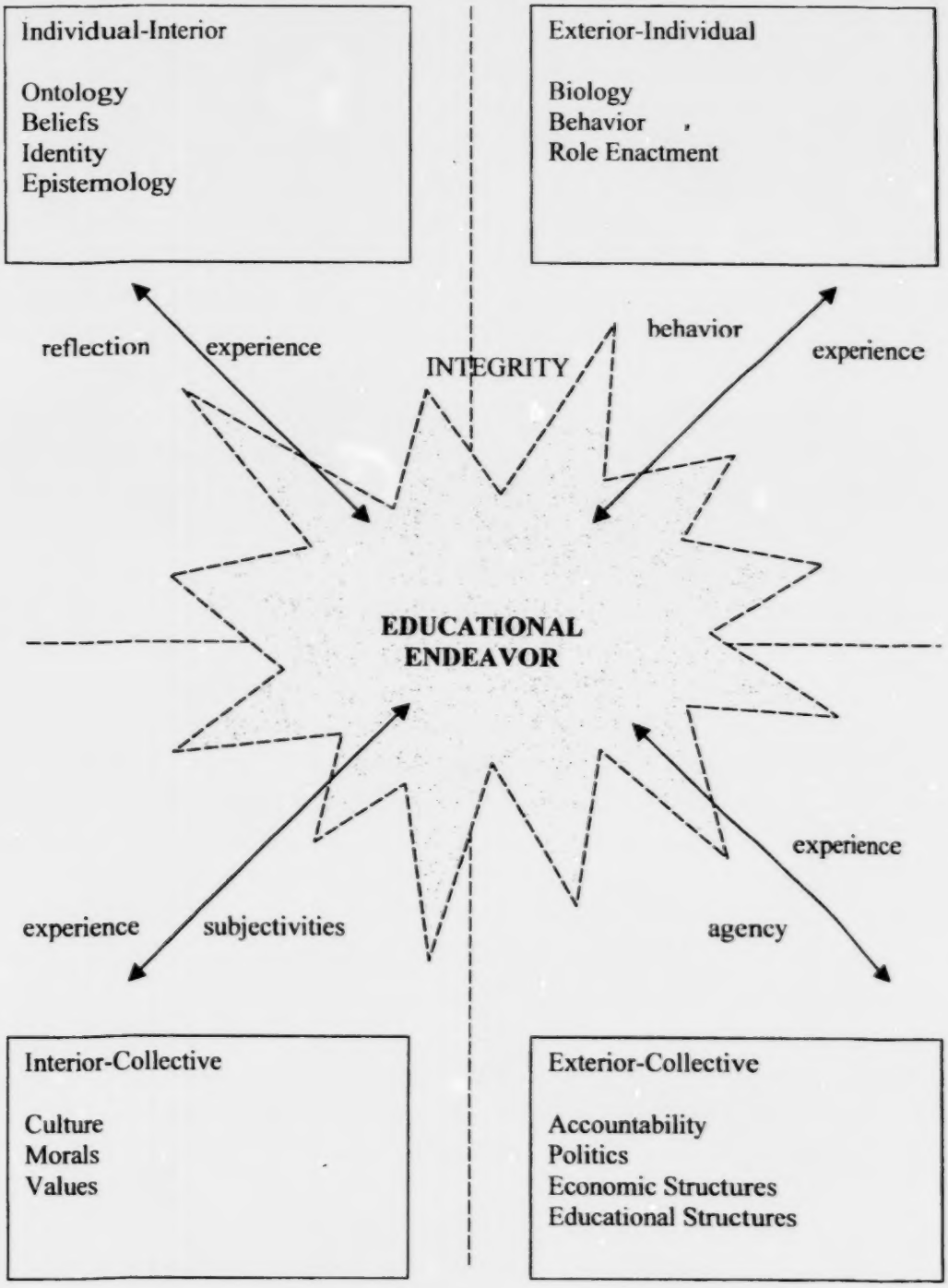

Figure 1
Modified Integral Model

Palmer (1998) asked, "Who is the self that teaches?" His answer, identity and integrity, mirrors the integral model. Identity is composed of the inner and the outer, biology and experiences, society and culture that come together into a self. Integrity is the wholeness that the self creates from these elements. For the purposes of this research, integrity is conceptualized as the way in which an individual navigates the intersections between culture, life history, biology, and society. Previous research "highlights the tension between individual teachers and their socio-cultural contexts, including schools, accountability movements, and science reform efforts" (Hancock, 2002). This research seeks to characterize the generation of integrity within the context of a specific science reform effort, with the intention of guiding the future direction of the program, including the generation of integrity among and within participants.

METHODOLOGY

Wilber (2000) proposed the application of the integral model to understanding human activity. The integral frame unites multiple perspectives with a spectrum of development. The multiple perspectives drawn together are the

> first-person or phenomenal accounts of the stream of consciousness as it is directly experienced by a person …; second-person communication of those facts, set in particular linguistic structures, worldviews, and background contexts …; and third-person scientific descriptions of the corresponding mechanisms, systems, and material networks, from brain structures to social systems (p. 192-3).

With this framework as a guide, researchers can pursue many questions in many ways that contribute to a more integral understanding.

As integral research, this study adopted a constructivist perspective and focused on description and interpretation of individual intention and collective socio-cultural phenomena. A constructivist research paradigm assumes that the understandings held by individuals are experiential and constructed from within (Denzin & Lincoln, 2000; Lincoln & Guba, 2000; Schwandt, 2000). In order to understand the constructed understandings of SPLASH participants, we adopted research strategies of applied ethnography and grounded theory. Applied ethnography assists people in making decisions and guiding the direction of change (Chambers, 2000). Such a research approach describes "what happens when cultural systems overlap as a result of some sort of deliberate, recent, or anticipated intervention" (p. 857). Grounded theory specifies "a set of clear guidelines from which [a researcher can] build explanatory frameworks that specify relationships among concepts" (Charmaz, 2000, p. 510). These guidelines include a cyclical process of data collection, coding, writing memos, and theoretical sampling. Woven together, these activities allow the researcher to formulate a well-developed representation.

As described above, the SPLASH program was implemented as part of the educational efforts of SAHRA, located at the University of Arizona, a large university in the southwestern US. SPLASH participants include a hydrologist, a policy expert, three science educators, five high school science teachers, a high school history teacher, a graduate fellow in natural resources, and an undergraduate fellow in engineering. SPLASH was initiated in the fall of 2001 and began curriculum module development during the spring of 2002.

Curriculum development and refinement continues. The second phase of SPLASH will involve implementation of the curriculum in a small number of schools. The third phase will involve curriculum modification and implementation in additional schools.

The data for this study consisted of interviews with participants, meeting notes, e-mail, curriculum modules, an Eisenhower grant proposal, and Hancock's journals. The interviews were semi-structured, using questions based on the research questions identified above (Appendix B). Data analysis was conducted with the data analysis program *NVivo* and followed the injunctions of grounded theory, involving cyclical coding, data collection, memo writing, and theoretical sampling. The quality of the understandings generated in this research is judged in terms of trustworthiness and authenticity (Guba and Lincoln, 1989; Wilber, 1998), achieved through thoughtful enactment of the process of grounded theory. In addition, as applied ethnography, quality criteria include the needs and judgments of stakeholders (Chambers, 2000).

FINDINGS

Description & Interpretation

The findings reported here are preliminary in nature, and data collection and analysis is continuing. The data associated with research questions one and two provide descriptions of the overall goals of SPLASH and the personal goals of individual participants. These descriptions form the basis for interpretations that characterize concerns, which have led to procedural and structural responses that address research question three, described in the next section.

Research question one asked what are participants' understandings of the overall goals of SPLASH in terms of content, educational reform, and practice. Data analysis revealed emphases on overall goals of creating a unique educational project and serving various audiences; content goals of cutting edge, interdisciplinary science and hydrologic literacy; reform goals of scientific literacy, inquiry learning, and quality professional development; and practice goals of including water in high school science and curriculum development. The data associated with these patterns are presented in Table 1. It should be noted that SAHRA's stated goal for SPLASH is to create a high school hydrology curriculum that advances hydrologic literacy.

Table 1
SPLASH Goals Data

Goals	Patterns	Data Examples
Overall Goals	Unique Educational Project	With the other five modules plus the proposed core, this multi-disciplinary course could be offered as a significant alternative to those more singular ones presently offered. (Howard, high school history teacher, e-mail)
		We not only have cutting edge science but cutting edge science education as well. (Fred, biology teacher and education graduate student, e-mail)
	Audiences	Not only did it seem like the area in K-12 where there was the least going on in water education was high school, but also almost nobody comes to college considering a degree in water resources. (Andrew, SAHRA policy expert, interview)
		There is a documented need to provide historically underserved and under-represented students with science instruction that is cognitively engaging and student-centered. The problem is particularly acute in hydrology, civil engineering and environmental engineering, where women, blacks and Hispanics are under-represented. (Eisenhower Grant Proposal, p. 7-8)
		The teachers came in with the science for all sort of attitude/mentality. So they said more people need access to this knowledge than just the kids that are at the advanced placement level. (Fred, biology teacher and education graduate student, interview)
Content Goals	Cutting Edge Science	If you can expose…high school kids…to the fact that hydrology is an interdisciplinary field that's on the cutting edge of remote sensing and super computing and certain areas of biology and isotopic chemistry, it opens their eyes. (Andrew, SAHRA policy expert, interview)
	Hydrologic Literacy	Key components of hydrologic literacy: 1) processes and components of water cycle, 2) water is essential to life, 3) natural effects of water in the environment, 4) access and limitations to water resources, 5) water contributes to the quality of human life, and 6) humans impact the quality and quantity of water resources. (paraphrased from SPLASH Summary document)
Reform Goals	Scientific Literacy	Hydrologic literacy enables people to use scientific principles and processes in making personal decisions and to participate in discussions of hydrologic issues that affect society. (Eisenhower Grant Proposal, p. 6)
		A strength of SPLASH is the things that we're able to do with water and water science and then translate into real science knowledge so that students can, according to the [National Science Education] Standards, students can make civic and personal decisions based on scientific knowledge (Fred, biology teacher and education graduate student, interview)
	Inquiry Learning	[SPLASH has a goal of] improved science education in Arizona that is more inquiry-driven, multi-disciplinary, and relevant. (Eisenhower Grant Proposal, p. 6)
	Quality Professional Development	Since there is a need to alter practice brought on by ownership of curricular modules, appropriate professional development can help teachers reveal their conceptions about science and teaching science, provide intelligible and useful alternative conceptions and then model how these conceptions can be translated into more student-centered practice required by the new curricula. (Eisenhower Grant Proposal, p. 8-9)
Practice Goals	Include Water	[It is] difficult to get high school science teachers to insert water related curriculum into their established courses. (Andrew, SAHRA policy expert, interview)
	Curriculum Development	Teachers in their 40s, who have been very successful, weren't about to completely change the way they approach putting together a curriculum. (Andrew, SAHRA policy expert, interview)

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Although it was anticipated that there would be a third category of practice goals titled pedagogical practice, no pattern has emerged. Participants have individual goals for their pedagogical practice (detailed below), but there is no articulated description of any for the SPLASH project. There is a suggestion in the Eisenhower proposal and the titles used in some modules (i.e., Santa Cruz Water History Inquiry One: When and How did the Santa Cruz River Form?) that inquiry is a central pedagogical element of SPLASH, but there is no data that describes the nature or details of inquiry in SPLASH. This gap is being addressed by continuing data collection and analysis and the continued activity of the SPLASH participants.

Research question two asked what are participants' understandings of their personal goals for involvement with SPLASH in terms of content, educational reform, and practice. Beyond the themes reported above, individual participants have personals goals that emphasize regional content, multiple literacies, involving other teachers, engaging students, student-centered practice, and inclusion of water. The data associated with these patterns is presented in Table 2.

Table 2
Participant Goals Data

Goals	Patterns	Data Examples
Content Goals	Regional	The six inquiries for Module 5 have been developed on an inquiry-based approach to understand the water history of southern Arizona. (Howard, high school history teacher, e-mail)
Reform Goals	Literacy	Literacy of all kinds, including our targeted water literacy, can best be planted and grown if empowered by genuine curiosity. (Howard, high school history teacher, e-mail)
	Involve Other Teachers	I want to share my module and the others that are completed with the rest of the teachers on staff.... I would like...to take what we have to our district curriculum committee towards getting it adopted as a course of study. Furthermore, it would also be presented as a model to develop introductory portions for lower grade levels-middle and elementary. (Howard, high school history teacher, e-mail)
		[Ideally, SPLASH would] take some of the most influential teachers in Tucson to work with them so that they have a good idea of the theory and practice of student-centered learning,...where students are constructing knowledge. And assist teachers in showing them how to use process to teach content. And put that into the curriculum, pilot some of those lessons, and begin to teach other teachers. (Fred, biology teacher and education graduate student, interview)
	Student Interest	[The teachers want to] use it as a way to make science more relevant to these kids lives and get them interested more generally in science and the possibility of going on to college (Andrew, SAHRA policy expert, interview)
Practice Goals	Student-Centered	[I see inquiry as] student questions based on student experience, which is then tied to content through teacher facilitation. (Fred, biology teacher and education graduate student, interview)
	Include Water	[I have begun to] integrate water awareness into my US history course (Howard, high school history teacher, e-mail)
		It was clear that it was difficult to get high school science teachers to insert water related curriculum into their established courses (Andrew, SAHRA policy expert, interview)

Process & Structure

The project and participant goals described above suggest concerns or points of tension around which much of SPLASH's challenges and creative efforts have focused. Consideration of the processes and structures constructed to address these concerns addresses research question three, how have participants achieved integrity in this context, and what are the key factors involved in this. Figure 2 introduces the key concerns (shaded) and how they were addressed.

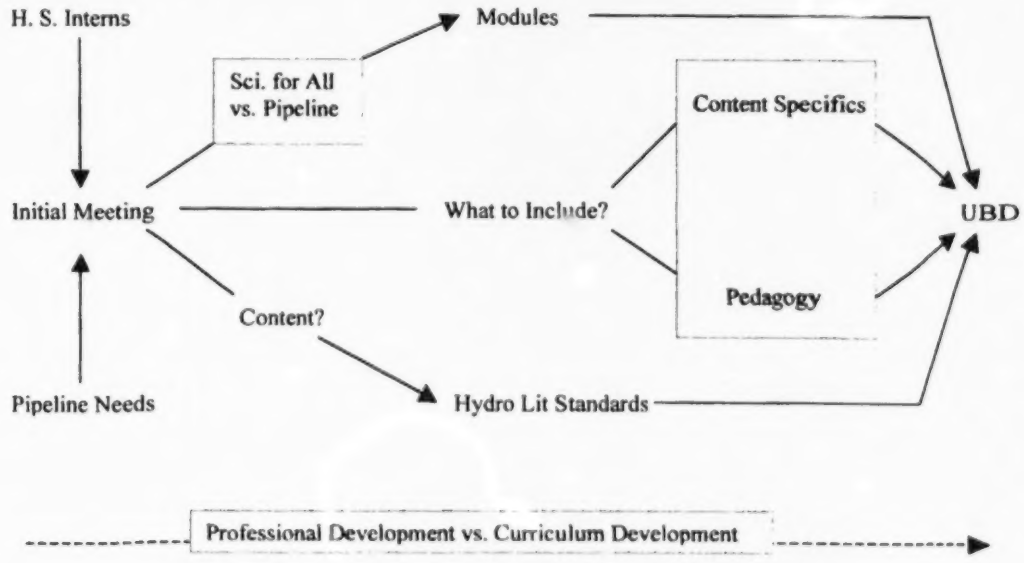

Figure 2
SPLASH Processes and Structures

Science for All vs. Pipeline

The first concern grew out of the question of audience. Was SPLASH being created as a pipeline to bring advanced students into hydrology and related sciences or as a vehicle to achieve science for all?

> There's a big difference between cherry-picking the most promising students to bring them into the field versus using [SPLASH] as a way to make science more

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> relevant to these kids' lives and get them interested more generally in science and the possibility of going on to college. I don't know. Right now, we're simultaneously trying to pursue both of those goals, and whether that's realistic or not, I don't know. (Andrew, SAHRA policy expert, interview)

As Andrew's answer to this question indicates, SPLASH is currently attempting to serve both audiences. In order to reach both audiences, SPLASH participants selected a modular structure to allow for flexible use in various content areas with students at varying levels for varying amounts of time. For example, there are plans for a freshman environmental science course to use only the core module as an introduction to hydrologic concepts and for an advanced senior hydrology course to use most of the content.

Focus on Content vs. Focus on Practice

Once the modular structure had been selected to address the question of audience, and the key elements of hydrologic literacy adopted to address the question of content, a third question emerged: What should be included?

> Matthew [a high school science teacher] was trying to get votes in his corner about how to set up curriculum. Most people were more interested about what content would go into the curriculum. I'm always more interested in what objectives are we starting with first and then what kind of evidence….So I was interested in making sure that everybody was on the same page philosophically. (Fred, biology teacher and education graduate student, interview)

This created a tension between those interested in focusing on a theoretical framework for pedagogy (how will the content be presented) and those focused on content specifics (now that we have the content areas defined, how will we go about populating them). This tension was addressed by adopting the Understanding by Design curriculum development model of Wiggins and McTighe (1998), which really addressed a third issue of how to go about creating the modules. The effect of this decision was to take the two issues off the table, leaving them to be determined by the creator of each module, and leaving the group with having agreed on how to go about the task.

Professional Development vs. Curriculum Development

The text of the Eisenhower grant proposal indicates that SPLASH was also envisioned as quality professional development by helping participating teachers develop hydrologic literacy and reform their practice or at least develop curriculum that uses reform-based practice. As a new administrator of SPLASH, Hancock struggled to understand the professional development aspects, which were explored in an interview with Fred.

> What I'm getting at here is are we calling it professional development because of these bureaucratic demands or is it really conceptualized by the people involved as a professional development experience. Are they there to grow as teachers or are they there perhaps for other reasons? (Elizabeth in interview with Fred, biology teacher and education graduate student)

There is no evidence that the SPLASH participants brought expectations for their own professional growth. Rather, they came in to use their expertise to write curriculum. While

this issue has not been addressed by any formal means, participants do pursue their own content and technical learning as needed in the form of independent reading or questions addressed to participating experts.

In summary, these preliminary findings indicate that all participants share a common conception of SPLASH as a multidisciplinary curriculum integrating science disciplines and other fields of knowledge to study water. Participants hold differing images of the goals of SPLASH in terms of educational reform and practice with conflicting interests in recruitment of qualified students into science, meaningful learning among students, cutting edge content, innovative practice, and professional development. These differences have forced participants to engage in active construction of integrity through the adoption of a modular structure and a commercial curriculum development template.

DISCUSSION & IMPLICATIONS

This research has been carried out as an applied ethnography, with a goal of guiding SPLASH's progress, especially the activity of Hancock in her work as the project administrator. As such, it has resulted in three outcomes so far. First, a SPLASH Summary document was created to articulate the project goals and content organization. Second, meeting time has been devoted to using the Understanding by Design module review process, which has facilitated conversation and evolving consensus on the pedagogical aspects of SPLASH. Third, although not introduced above, module development has not progressed as rapidly as planned, so another document, SPLASH 2003 and Beyond, was developed to establish a timeline, targets for success, task assignments, and needs.

The activities described above were initiated and crafted by Hancock based on her knowledge of the group and the findings of this study. They were presented to the participants for feedback but were not made by the group. Did this weaken the power and influence of participants? Is it better to acknowledge that a power structure does exist and use structures that help those with more power act wisely with others' voices as a guide? It is clear that the teacher participants value having structural and administrative tasks handled by others, freeing them to express their voices in module conception and creation. These issues remain unresolved for SPLASH at this time.

The fourth research question asked how does this effort inform the educational practices of entities like SAHRA. Two points have emerged. First, the tension over audience is critical and permeates all that SAHRA does educationally. A critical element of SPLASH's struggle with this issue has been the active negotiation about this issue among all participants. Second, as a construction in progress, SPLASH has considerable flexibility, allowing it to evolve over time. This has facilitated creativity and improvements but has caused the project to move more slowly than anticipated or desired. Similar projects should engage teachers as co-creators, directly address issues of audience, anticipate delays, and embrace flexibility.

This material is based on work supported in part by SAHRA (Sustainability of Semi-Arid Hydrology and Riparian Areas) under the STC Program of the National Science Foundation, Agreement No. EAR-9876800.

APPENDIX A
SAHRA'S EDUCATIONAL ACTIVITIES AND AUDIENCES

Who / What	Graduate Students	Undergraduate Students	K-12 Teachers	High School Students	K-8 Students
New Curricula	Graduate Seminars	Arizona Water Issues		**SPLASH**	**Biosphere 2 Passport to Learning**
Professional Growth	***MSEng*** ——— Tribal Watersheds*	*CREST Centers**	Inquiry and Water Issues	SACNAS*	**AZ Prop 301** ——— **NAU Tribal Education***
Research Experiences	Research Assistantships*	Research Experience for Undergraduates*	**Teacher Research**	HS Interns	***Data Networks*** --------- GLOBE
Extended Learning	Outreach Opportunities		***Website*** ---------- EcoStart*	**Res. Mentors** ——— **CATTS**	***Camp Monsoon****

APPENDIX B
INTERVIEW PROTOCOL

1. What is the goal of SPLASH?
2. Describe how you became involved in SPLASH.
3. Why did you become involved in SPLASH?
4. What are your personal goals for involvement in SPLASH?
5. Have those goals changed over time? Why and how?
6. How has involvement in SPLASH been rewarding to you?
7. How has involvement in SPLASH been challenging for you?
8. How have you addressed the challenges you have faced in your involvement in SPLASH?
9. How has SPLASH addressed the challenges it has faced?
10. What have you learned from your involvement in SPLASH (about science, teaching practice, educational reform, and yourself?
11. Please describe your role in SPLASH.
12. Please describe the role of the other participants in SPLASH (name the scientists, teachers, and educators including myself)?

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